

ELECTRONIC FUNDAMENTALS

EXPERIMENT LESSON 24

POWER-AMPLIFIER EXPERIMENTS



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Experiment Lesson 24

OBJECT

To study the characteristics of the power-amplifier tube and the features of the power-amplifier stage.

INFORMATION

In order to produce sound by setting air in motion, the loudspeaker must be supplied with electrical power. The loudspeaker converts the electrical power into mechanical power to produce sound. The purpose of the power-amplifier stage in a radio receiver is to produce sufficient electrical power output to operate the loudspeaker.

Tubes chosen for a power-amplifier stage must be capable of handling the high currents involved. They usually have a high transconductance, so that the input signal can produce large a-c current changes to develop the high a-c power needed.

In this experiment, you will study the features of a typical power-amplifier tube, and the differences in operation of voltage and power amplifier stages.

EQUIPMENT NEEDED

- One 6K6-GT tube
- One speaker, with mounting bracket and hardware
- One output transformer
- One 470 k-ohm resistor
- One 470-ohm resistor
- One 0.05- μ f capacitor (remove from capacitor board)
- One octal socket, with mounting hardware

One 2-lug terminal strip

One 1-lug terminal strip

One rubber grommet

Signal generator

Multimeter

Clip lead

Piece of Cardboard, 5" x 8"

JOB 24-1

To become familiar with the 6K6-GT characteristics as given in the tube manual.

Procedure.

Step 1. Look up the 6K6-GT tube in the tube manual, and fill out the following:

Type of tube: POWER PENTODE

Type of base: OCTAL SOCKET

Heater: voltage 6.3 volts; current 1.4 ma

Directly or indirectly heated cathode:

indirectly heated

Maximum plate voltage: 315 volts

Maximum plate dissipation: 8.5 watts

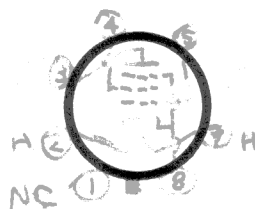
*Maximum screen voltage: 275 volts

*Maximum screen dissipation: not given watts

*Mutual conductance: 2500 μ mhos

*Plate resistance: 90,000 ohms

Step 2. Draw the basing diagram in the space below.



*Based on a plate voltage of 250 volts

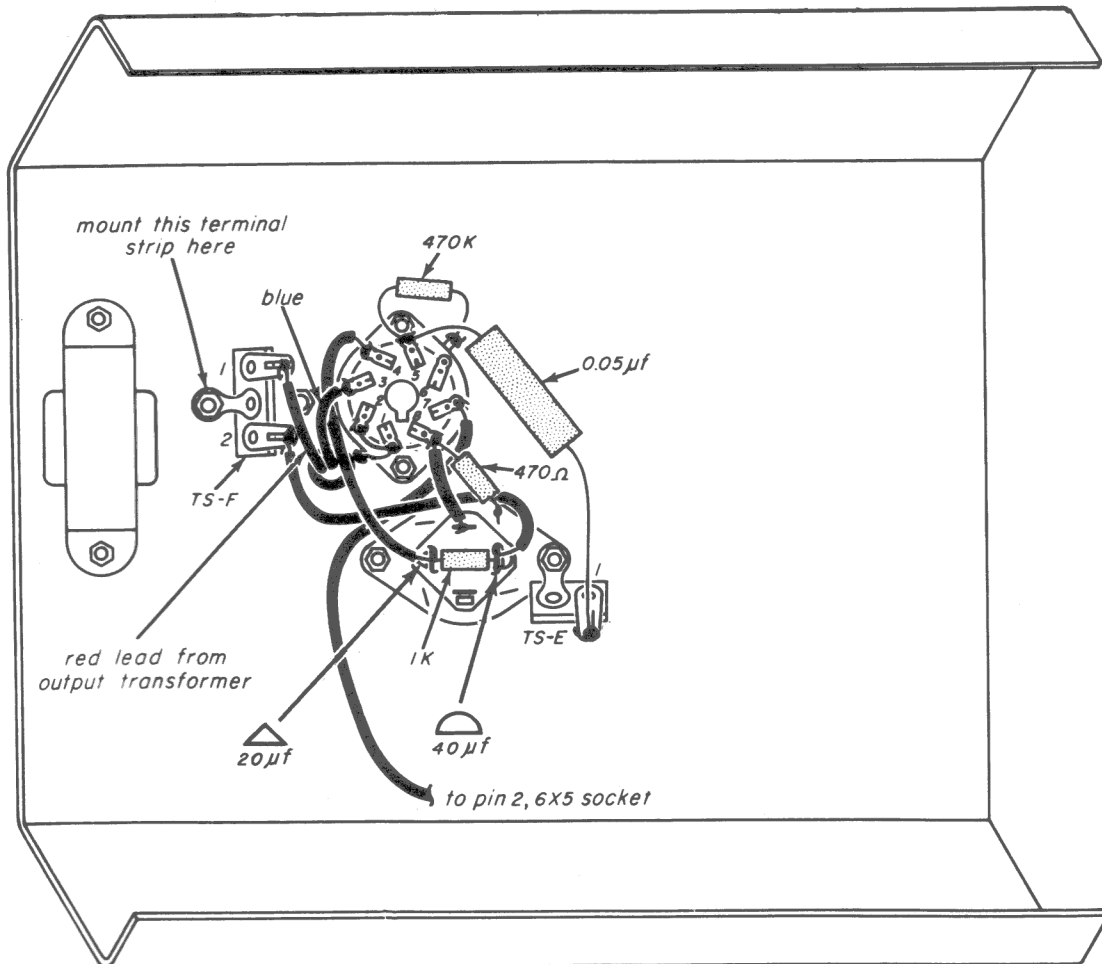


Fig. 24-1

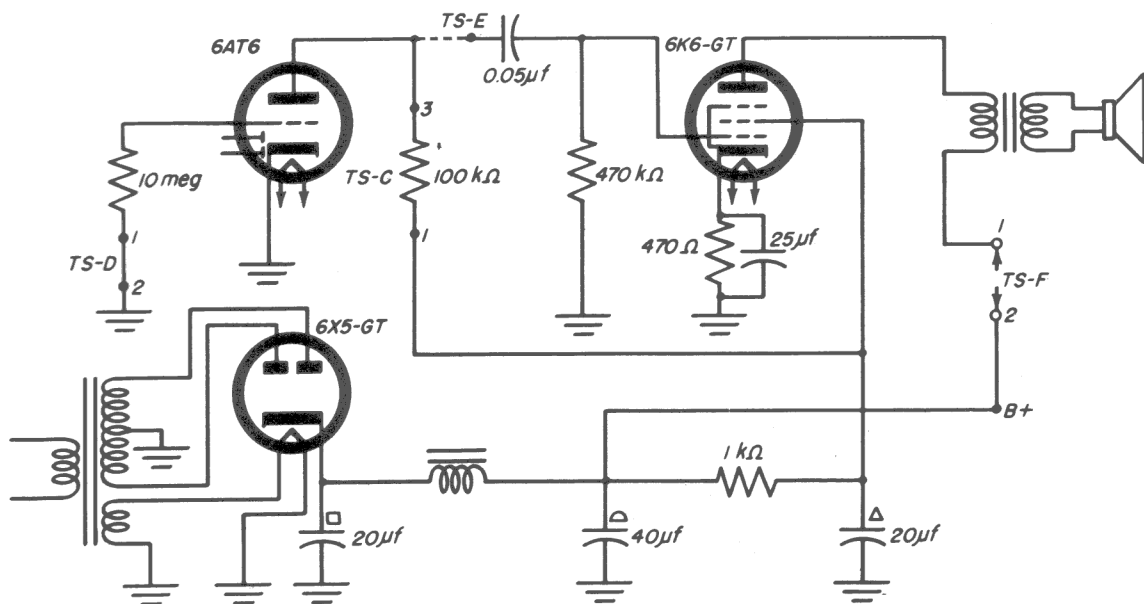


Fig. 24-2

JOB 24-2

To prepare the radio-receiver chassis for the next series of experiments.

Procedure.

Step 1. Disconnect the 5k-ohm and 10k-ohm resistors and the wire connected to TS-B.

Step 2. Disconnect the 1,000-ohm resistor at TS-B, and connect it across the electrolytic capacitor terminals marked with a $\triangle$ and a $\bigcap$, as shown in Fig. 24-1.

Step 3. Remove TS-B and put it aside.

Step 4. Mount an octal socket, using 6-32 x 1/4-inch screws and hex nuts, in the hole next to the electrolytic capacitor, as shown in the figure. Make sure the keyway on the socket points to the rear of the chassis as shown. This tube socket is for the 6K6-GT tube.

Step 5. Install a 3/8-inch rubber grommet in the small hole next to the octal socket.

Step 6. Install a 1-lug terminal strip, of the type shown in the figure, using the electrolytic-capacitor mounting screw to hold this terminal strip. This terminal strip will be referred to as TS-E. Label it on your chassis.

Step 7. Obtain a piece of stiff cardboard about 5 x 8 inches and fasten it in front of the speaker, using tape or rubber bands to hold it in place. This will prevent the

paper cone of the speaker from being damaged.

Step 8. Mount the output transformer on the speaker, as shown in Fig. 24-3. Attach the speaker bracket to the speaker as shown in this figure, but do not tighten the screws completely.

Step 9. Mount the speaker on the chassis, using two 6-32 x 1/4-inch screws and hex nuts, but do not tighten the screws completely. At the same time install a 2-lug terminal strip underneath the chassis using one of the speaker mounting screws to hold it as shown in Fig. 24-1. This terminal strip will be referred to as TS-F. Label it on your chassis.

Step 10. Fasten the rim of the speaker to the chassis using a 8 x 3/8-inch self-tapping screw, as shown in Fig. 24-4. Adjust the bracket so that speaker and bracket are vertical, and tighten all screws.

Step 11. Cover each secondary lead with a piece of spaghetti that will leave 1/2 inch of the lead exposed. Solder the leads to the voice coil terminals on the speaker. (Use temporary solder connections for both leads.)

Step 12. Pass the red and blue primary leads of the output transformer down through the grommet to the underside of the chassis. Turn the chassis upside down, and support it with a block of wood so that it is steady.

Step 13. With a piece of hookup wire, connect pin 7 of the 6K6-GT socket to pin 2 of the 6X5 socket. Dress the wire as shown

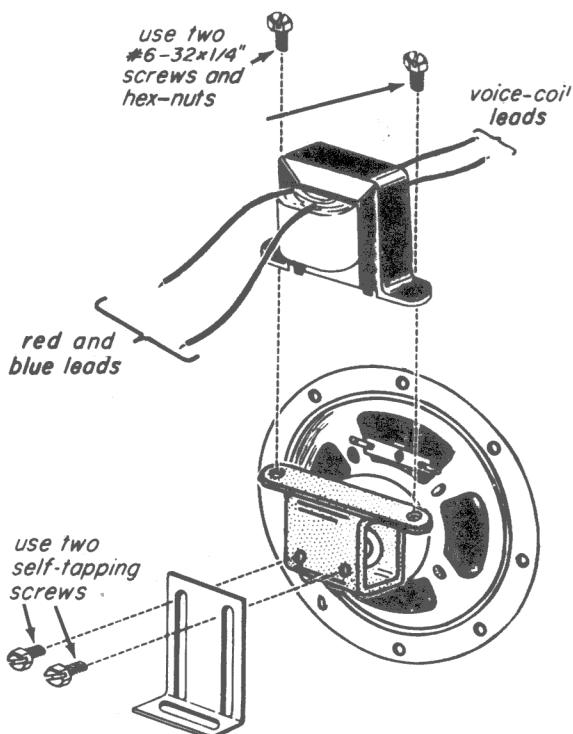


Fig. 24-3

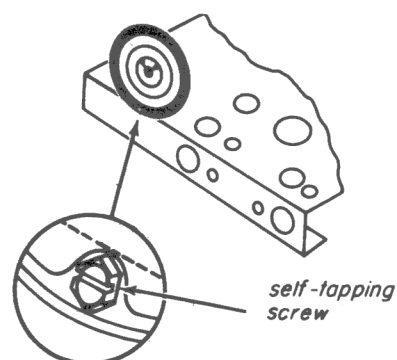


Fig. 24-4

in Fig. 24-1, and keep it down close to the chassis.

Step 14. With a piece of bare wire, connect pins 1 and 2 on the 6K6-GT tube socket together and to the ground lug near pin 2 on the socket, as shown.

Note: Use temporary solder connections for the wiring that follows.

Step 15. Connect a 470-ohm resistor from pin 8 on the 6K6-GT socket to a ground lug of the electrolytic capacitor, and a piece of hookup wire from pin 8 of the tube socket to the unlabeled (25 μ f 25 volts) terminal of the electrolytic capacitor.

Step 16. Connect the blue lead of the output transformer to pin 3 of the 6K6-GT tube socket.

Step 17. Connect the red lead of the output transformer to lug 1 of TS-F.

Step 18. Connect a piece of hookup wire between lug 2 of TS-F and the electrolytic capacitor terminal marked with a $\cap$.

Step 19. Connect a piece of hookup wire between pin 4 of the 6K6-GT tube socket, and the electrolytic capacitor terminal marked with a $\triangle$.

Step 20. Connect an 0.05- μ f capacitor from pin 5 of the 6K6-GT socket to lug 1 of TS-E.

Step 21. Connect a 470 k-ohm resistor between pin 5 of the 6K6-GT tube socket and a ground lug on this tube socket.

When you have finished this wiring, your new wiring should look like that shown in Fig. 24-1, in which the new wiring added in Job 24-2 is shown. A schematic diagram of this circuit is shown in Fig. 24-2.

JOB 24-3.

To check the power amplifier stage by means of voltage measurements.

Procedure.

Step 1. Set up the multimeter to the 500 VDC range.

Step 2. Insert the 6K6-GT tube in its socket.

Step 3. Connect your alligator clip lead across lugs 1 and 2 of TS-F.

Step 4. Plug in the receiver line cord and allow the tubes to warm up.

Step 5. Measure the voltage between ground and each pin of the 6K6-GT tube socket. Set the meter to the appropriate scale and function setting where necessary. Record the readings in Table A, and com-

TABLE A - 6K6-GT

Pin No.	Your Readings	Given Readings
1		0
2		0
3	260	240 VDC
4	262	245 VDC
5		0
6	No connection	No connection
7	6.6	6.3 VAC
8	18	16 VDC

pare them with the voltages given. If they do not agree within $\pm 20\%$, unplug the line cord and recheck your wiring against Fig. 24-1.

Step 6. Disconnect the line cord when you have completed these readings.

EXPERIMENT 24-1

To measure the power output of the 6K6-GT power amplifier stage, and to compare its operating characteristics with that of the voltage-amplifier stage.

Procedure.

Step 1. Plug in the line cord of the signal generator; turn it on, and allow it to warm up.

Connect the signal generator cable to the AF OUTPUT connector, and turn the bandswitch to the Band X position.

Step 2. Connect the signal-generator cable to the grid (pin 1) of the 6AT6 voltage amplifier, and the ground clip of this cable to any convenient ground point on the chassis.

Step 3. Set up the multimeter for the 75 VAC range, and put the positive meter test lead in the OUTPUT jack. Connect the positive test lead to the plate (pin 7) of the 6AT6 tube, and the negative lead to the chassis.

Step 4. Plug in the radio receiver, turn it on and allow it to warm up.

Step 5. Set the AF OUT/INT MOD control at minimum. Then increase the output to produce 50 volts at the plate of 6AT6. The output of the signal generator is now about 1 volt. Do not disturb the setting of the AF OUT/INT MOD control unless instructed to do so.

Step 6. Calculate the *alternating current* in the plate circuit of the 6AT6 voltage amplifier stage.

$$I = \frac{E}{R} = \frac{50}{100,000} = \underline{.0005} \text{ ma a.c.}$$

Step 7. Calculate the a-c power output of the voltage amplifier stage:

$$P = \frac{E^2}{R} = \frac{2,500}{100,000} = \underline{.025} \text{ watts}$$

Step 8. Disconnect the line cord of the receiver.

Step 9. Connect the signal generator cable to lug 1 of TS-E and the ground clip of the cable to any convenient ground point.

* If the output of the loudspeaker disturbs you or your family, you can substitute a dummy load for the loudspeaker voice coil. Cut off a 6" length of nichrome wire. Mount it on a small board as shown in Fig. 24-5. Extend the voice coil leads of the output transformer and connect them to the terminal lugs, as shown.

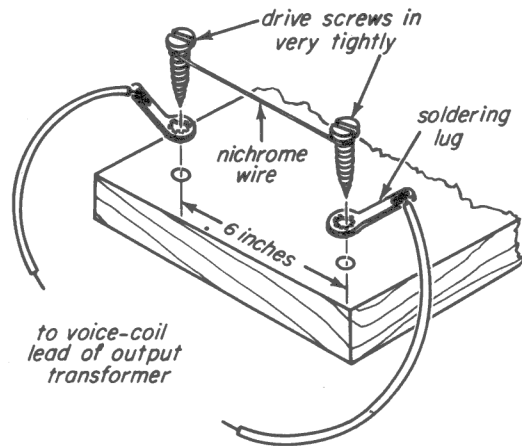


Fig. 24-5

Step 10. Connect the positive test lead of the multimeter (which is to be left in the OUTPUT jack on the meter) to the plate (pin 3) of the 6K6-GT power amplifier tube, and the negative test lead to the chassis.

Step 11. Plug in the a-c line cord, and allow the receiver to warm up.*

Step 12. Read the a-c voltage at the plate of the tube as shown by the meter. Record your reading here:

17
volts a.c.

Step 13. Unplug the receiver line cord.

Step 14. Using 7,600 ohms as the impedance of the primary of the output transformer, calculate the *alternating current* in the plate circuit of the 6K6-GT power amplifier stage:

$$I = \frac{E}{R} = \frac{17}{7,600} = \underline{2.2} \text{ ma}$$

Step 15. Calculate the a-c power output of the power amplifier stage:

$$P = \frac{E^2}{R} = \frac{289}{7,600} = \underline{.038} \text{ watts}$$

How does the voltage output of the power amplifier compare with that of the voltage-amplifier stage for the same input signal?

How does the power output of the power-amplifier stage compare with that of the voltage amplifier stage for the same signal input?

less
More

How does the a-c current in the plate circuit of the two stages compare? *more in Power amp.*

How do you explain the much greater power output in the case of the power amplifier? *?*

Discussion. When the input signal is adjusted in Step 5 to produce 50 volts output across the 6AT6 voltage amplifier load resistor, typical results for the experiment are as follows:

Alternating current in the 6AT6 plate circuit

— 0.50 ma

A-C power output of the 6AT6 stage

— 0.025 watts

Voltage output of the 6K6-GT stage

— 17 volts

Alternating current in the 6K6-GT stage

— 2.24 ma

A-C power output of the 6K6-GT stage

— 0.038 watts

The results of this experiment show that for the same a-c signal input, the voltage output of the 6AT6 stage is much greater than the voltage output of the 6K6-GT stage. However, for the same signal input, the power output of the 6K6-GT stage is almost twice as great. This is because the same signal input to the power amplifier produces more than four times as much a-c current in the plate.

Another most important feature of power amplifiers is the maximum power output that can be obtained from them. One volt of signal is about the most that can be applied to the 6AT6 stage without considerable distortion. Thus, about 0.025 watts is the maximum output that can be obtained from the voltage-amplifier stage. This amount of power produces only a barely audible sound. Much larger input signals can be applied to the power amplifier to produce the output power needed to operate the loudspeaker at full volume.

EXPERIMENT 24-2

To compare the output of the 6K6-GT when operated triode-connected with that of the 6K6-GT when operated as a beam-power tube.

Procedure.

Step 1. Disconnect, at the Δ terminal of the electrolytic capacitor, the wire going to pin 4 of the 6K6-GT tube socket, and connect it to pin 3 of the tube socket, so that pins 3 and 4 of this tube socket are connected together. Now the 6K6-GT is triode-connected.

Step 2. Make sure that the signal generator is on and the AF OUT/INT MOD control is still at the setting determined in Step 5 of Experiment 24-1.

Step 3. Plug in the a-c line cord of the receiver, and allow it to warm up.

Step 4. Switch to the 15 VAC range. Check that the positive test lead of the meter is in the OUTPUT jack. Measure the output voltage at pin 3 of the 6K6-GT tube socket.

50.95

Step 5. Unplug the a-c line cord.

Step 6. Using 7,600 ohms as the impedance of the primary of the output transformer, calculate the alternating current in the plate circuit of the triode connected 6K6-GT power amplifier stage:

$$I = \frac{E}{R} = \frac{50.95}{7,600} = 0.0067 \text{ ma}$$

Step 7. Calculate the a-c power output of the triode-connected 6K6-GT power amplifier stage:

$$P = \frac{E^2}{R} = \frac{2,615}{7,600} = 0.344 \text{ watts}$$

How does the power output of the triode connected stage compare with that of the pentode-connected stage? *10 x less*

Discussion: Changing the 6K6-GT from pentode to triode operated reduces the a-c output voltage from about 17 volts to about 6 volts, and the output power from 0.038 watts to 0.0047 watts. Thus, with the signal input constant, changing from pentode operation reduces the power output almost ten times. As this experiment shows, pentodes have a greater *power sensitivity*; that is, they can produce more power output for a given signal input. This is primarily due to pentodes having a much greater amplification factor than triodes.

EXPERIMENT 24-3

To measure the efficiency of a power amplifier; that is, to measure the ratio of the a-c power delivered to the output transformer to the d-c power input provided by the power supply.

Procedure.

Step 1. Unsolder the lead connecting together pins 3 and 4 of the 6K6-GT tube socket at pin 3, and reconnect it back to the triangle terminal of the electrolytic capacitor, so that pin 4 of the 6K6-GT tube socket is connected to this electrolytic-capacitor terminal.

Step 2. Plug in the receiver line cord and allow the tubes to warm up.

Step 3. Check to see that the signal generator is on and that the terminals of the output cable are connected to lug 1 of TS-E and ground. Connect the meter across the signal generator output, and adjust the AF OUT/INT MOD control to obtain 10 volts output, measured on the 75 VAC scale.

Step 4. Turn the meter range switch to the 300 VAC position. Measure the a-c voltage from pin 3 of the 6K6-GT tube to the

chassis. Record your reading here:

175
volts a.c.

Step 5. Calculate the a-c power using 7,600 ohms as the load resistance.

$$P = \frac{E^2}{R} = \frac{E^2}{7,600} = \frac{30625}{7600} \text{ watts} = 4 \text{ watts}$$

Step 6. Set up the multimeter service on the 500 VDC range. Remove the positive test lead from the OUTPUT jack and replace it in the + jack. Do not forget to change the FUNCTION switch from AC to DC.

Step 7. Measure the d-c voltage at the plate (pin 3) of the 6K6-GT tube. Record your measurement here:

254
volts d.c.

Step 8. Unplug the a-c line cord.

Step 9. Remove the clip lead from lugs 1 and 2 of TS-F.

Step 10. Set up the multimeter for service on the 100 MA range, and connect it in place of the clip lead removed in the previous step (positive meter test lead to lug 2 and negative meter test lead to lug 1 of TS-F.)

Step 11. Reconnect the a-c line cord and allow the tubes to warm up.

Step 12. Measure the d-c plate current and record it here:

2.8
ma d.c.

Step 13. Unplug the line cord and disconnect the meter.

Step 14. Disconnect and put aside the wire from lug 2 of TS-F to the Δ terminal

of the electrolytic capacitor. Also disconnect the red lead of the output transformer from lug 1 of TS-F and connect it to the Δ terminal of the capacitor. Terminal strip F should now be free of any wires, so that it can be used in the next experiment.

Step 15. Calculate the d-c power input. (Do not forget to change milliamperes to ampere before multiplying.)

$$P = E \times I = \frac{240 \times 7.1}{1000} \text{ watts}$$

Step 16. Calculate the efficiency, using the a-c power output as calculated in Step 5.

$$\% \text{ efficiency} = \frac{\text{output}}{\text{input}} \times 100$$

$$= \frac{4}{7.1} \times 100 = 56.70 \%$$

Discussion. When the signal-generator audio input to the power-amplifier stage is adjusted to 10 volts, the actual voltage applied to the grid of the tube is about 11.3 volts. The meter reading is lower due to the loading effect of the meter on the signal generator. Since the peak voltage of an a-c wave is 1.4 times the rms value, the actual peak voltage being applied to the grid of the tube is 16 volts. This is the highest signal voltage that can be applied to the tube without overcoming the bias, drawing grid current, and causing serious distortion.

With this signal input, the a-c output voltage measured at the plate of the 6K6-GT tube is about 165 volts, and the a-c power output to the output transformer is 3.6 watts. The input is about 240 volts d.c., and the d-c plate current is 32 ma, making a d-c input power of about 7.7 watts. The efficiency is then 47 percent.

The maximum theoretical efficiency, of the stage is 50 percent. In practical pentode power amplifiers, the efficiency varies from about 28 percent to 43 percent if the distortion is to be kept below 10 percent.

EXPERIMENT 24-4

To study the effect of disconnecting the voice coil of a loudspeaker when power is applied to the receiver.

Information. In many radio and television receivers, the loudspeaker is connected across the output transformer by means of a speaker plug. This makes it very easy to disconnect the speaker, and is very convenient for servicing when the chassis must be removed from the cabinet.

However, in some cases, carelessly disconnecting the speaker while the receiver has power applied to it may cause damage to the output tube, as you will see in this experiment.

Procedure.

Step 1. Disconnect, at the Δ terminal of the electrolytic capacitor, the wire from pin 4 of the tube socket and connect this wire to lug 1 of TS-F.

Step 2. Connect your clip lead between lug 1 of TS-F and the electrolytic capacitor terminal marked with a Δ .

Step 3. Check to see that the signal generator is on and that the output cable is still connected to lug 1 of TS-E and ground. Turn the AF OUT/INT MOD control to minimum (all the way counterclockwise).

Step 4. Set up the multimeter to the 500 VDC range.

Step 5. Plug in the a-c line cord of the receiver, and allow the tubes to warm up.

Step 6. Measure the d-c screen grid voltage at pin 4 of the 6K6-GT tube socket. (Positive meter test lead to pin 4, negative meter test lead to chassis. Record it here:

260

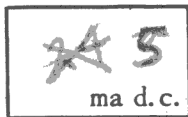
volts d.c.

Step 7. Remove the a-c line cord. Then remove the clip lead from lug 1 of TS-F to the electrolytic capacitor.

Step 8. Reconnect the a-c line cord to an a-c outlet, and allow the tubes to warm up.

Step 9. Set up the multimeter to the 100 ma range, and connect it in place of the clip lead. (Positive test lead of the meter to the triangle electrolytic terminal, negative meter test lead to lug 1 of TS-F.)

Step 10. Measure the d-c screen current and record it here:



Step 11. Unplug the line cord and disconnect the meter, and replace the clip lead as in Step 2.

Information. The product of the d-c screen voltage and the d-c screen current gives the power in watts dissipated in the screen grid. This power is converted into heat, raises the temperature of the screen-grid wires, and should not be greater than the maximum allowable wattage given in the tube manual. The maximum screen dissipation for the 6K6-GT, as given in the tube manual, is 2.8 watts.

Step 12. Calculate the screen dissipation, using the screen voltage and current, as measured in Steps 6 and 10. (Remember to change milliamperes to amperes before multiplying.)

$$P_{\text{screen grid}} = E \times I = \frac{260}{1000} \times 5 \text{ watts} = 1.3$$

This is the normal screen dissipation. How does this compare with the maximum allowable screen dissipation of this tube as given in the tube manual?

Step 13. Unsolder one of the secondary leads and put a small piece of tape on it to prevent it from shorting to the frame or to the voice-coil terminal.

Step 14. Repeat Steps 4 through 12. Note whether there are any significant changes in voltage, current, and screen dissipation.

Record your results here.

D-C screen voltage: 260 volts
D-C screen current: 5 ma
Screen dissipation: 1.3 watts

Step 15. Turn the AF OUT/INT MOD control to maximum and quickly repeat Steps 4 through 12. Record your results here:

D-C screen voltage: 260 volts
D-C screen current: 13 ma
Screen dissipation: 3.38 watts

Discussion: Typical results (10 volts a-f input) with the voice-coil connected are:

D-C screen voltage 245 volts
D-C screen current 5 ma
Screen dissipation 1.2 watts

With the voice coil disconnected and maximum signal input, typical results are:

D-C screen voltage: 235 volts
D-C screen current: 22 ma
Screen dissipation: 5.17 watts

Opening the voice coil has no effect until there is a signal input to the power amplifier. Then the screen current increases considerably and the screen dissipation of the tube is exceeded. If a speaker can be unplugged from a receiver, be sure to keep the volume turned down when the speaker isn't connected.

Screen dissipation increases because disconnecting the voice coil from the secondary of the output transformer increases the impedance of the primary. Therefore the a-c current produced by the input signal is prevented from flowing in the plate circuit and flows in the screen circuit instead, causing increased average d-c screen current.

EXPERIMENT 24-5

To study the effect on the output tube of disconnecting the plate voltage

Procedure.

Step 1. Unsolder the blue output transformer lead from pin 3 of the 6K6-GT tube

socket and tape the end of the lead.

Caution: Perform the remaining steps of this experiment as quickly as possible to avoid overheating the screen grid of the tube.

Step 2. Set up the multimeter to the 500 VDC range.

Step 3. Plug in the a-c line cord of the receiver, and allow the tubes to warm up.

Step 4. Measure the d-c screen-grid voltage at pin 4 of the 6K6-GT tube socket. (Positive meter test lead to pin 4, negative meter test lead to chassis.) Record it here:

260
volts d.c.

Step 5. Remove the a-c line cord. Then remove the clip lead from lug 1 of TS-F to the electrolytic capacitor.

Step 6. Reconnect the a-c line cord to an a-c outlet, and allow the tubes to warm up.

Step 7. Set up the multimeter to the 100 MA range, and connect it in place of the clip lead. (Positive test lead of the meter to the triangle electrolytic terminal, negative meter test lead to lug 1 of TS-F.)

Step 8. Measure the d-c screen current and record it here:

25
ma d.c.

Step 9. Unplug the line cord and disconnect the meter.

Step 10. Calculate the screen dissipation, using the screen voltage and current, as measured in Steps 4 and 8. (Remember to change milliamperes to amperes before multiplying.)

6.5 watts

How does this compare with the maximum allowable screen grid dissipation?

over twice

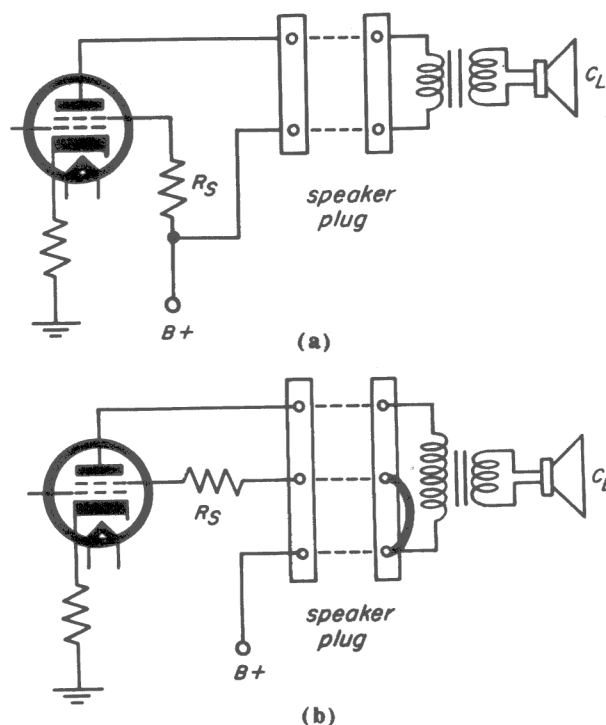


Fig. 24-6

Discussion. The normal screen dissipation for this tube is the same as obtained in the previous experiment. When the plate load is disconnected, the d-c plate voltage is approximately 235 volts, and the d-c screen current increases to approximately 24 ma. This voltage and current give a screen dissipation of about 5.6 watts, which is twice the allowable screen dissipation of the tube.

The reason for the increased current is that when the plate voltage is removed, the screen is the only positive element in the tube, and it attracts all the current to itself. Much more than normal current thus flows in the screen circuit, and the screen dissipation is increased.

For this reason, the plate circuit of a pentode tube should never be opened while screen voltage remains connected. This should be kept in mind whenever a speaker plug is wired for a speaker where the output transformer is mounted on the speaker frame. Never use a 2-prong plug, as shown in Fig. 24-6a, because disconnecting the speaker will remove plate voltage while leaving screen voltage connected. The arrangement shown in Fig. 24-6b, in which a link in the

speaker plug breaks the screen circuit when the speaker is disconnected, is the proper method.

JOB 24-4

To complete the power-amplifier wiring.

Procedure.

Step 1. Solder the blue lead of the output transformer back to pin 3 of the 6K6-GT tube socket.

Step 2. Disconnect, at lug 1 of TS-F, the lead from pin 4 of the 6K6-GT tube socket, and connect it to the Δ terminal of the electrolytic capacitor.

Step 3. Connect a wire between the plate (pin 7) of the 6AT6 tube and lug 1 of TS-E.

Step 4. Reconnect the voice coil lead to the speaker.

